Industry 4.0 in Finland

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8 authors, including:

Iqra Zafar Khan
University of Agriculture Faisalabad

Osmo Kauppila
University of Oulu

Jukka Majava
University of Oulu

Marko Jurmu
VTT Technical Research Centre of Finland

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Towards Twin Transition

Iqra Sadaf Khan, Osmo Kauppila, Jukka Majava, Marko Jurmu, Jan Olaf Blech, Elina Annanperä, Marko Jurvansuu, and Susanna Pirttikangas

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3.1 INTRODUCTION AND COUNTRY BACKGROUND

As the European Union's (EU) leader in digitalization performance (European Commission 2019, 2020) and its most sparsely populated nation, Finland is a Nordic country of 5.5 million inhabitants, with few political risks, high-end infrastructure, and good quality logistics (Kaivo-Oja *et al.* 2018). Finland is among the leaders in many global rankings, such as PISA (Schleicher 2019), anti-corruption (Transparency International 2020), happiness (Helliwell *et al.* 2020), and innovation (Cornell University *et al.* 2020).

In Industry 4.0 rankings, Finland also ranks near the top. Castelo-Branco *et al.* (2019) place Finland as a leader alongside the Netherlands in Industry 4.0 readiness in manufacturing in the EU. Atik and Ünlü (2019) rank Finland second in Europe in Industry 4.0 performance. Additionally, Sung (2018) investigated global Industry 4.0 competitiveness based on UBS (2016), WEF (2016), and IMD (2017) and ranked Finland second behind Singapore.

The Finnish industry is based on high-value-added export-oriented manufacturing (Ciffolilli and Muscio 2018) due to its small domestic market and price competition not being an option. To remain competent, Finnish manufacturers need to be flexible, reliable, and able to provide state-of-the-art technology (Kaivo-Oja *et al.* 2018). Examples of export companies in Finland include Stora Enso (wood and paper products), Kemira (chemicals), Wartsila (marine, power), Neste (oil products),

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Nokia (information and communications technology), KONE (escalators), SSAB (steel products), ABB (robotics, power), and Ponsse (forest harvesters). Recently, the Finnish game industry has had success stories as well, such as Rovio (Angry Birds) and SuperCell (Clash of Clans).

Regarding exports, in 2005, nearly 86 percent of Finnish exports were industrial goods, but the share of services is currently 33 percent (Confederation of Finnish Industries 2020). Still, most exports are physical products. In 2019, the total goods exported were worth 64.8 billion euros with 2 percent annual growth, while the service exports totaled 31.7 billion euros in 2019 with 17 percent annual growth (Confederation of Finnish Industries 2020). The Finnish industry depends on its international supplier base, with more than 80 percent of intermediate goods and components coming from abroad (Ali-Yrkkö and Kuusi 2020).

The Finnish economy has fluctuated between periods of growth and turmoil due to events such as the collapse of Eastern trade accompanied by a financial crisis (1990–1993), a global financial crisis (2007–2009), and the collapse of Nokia's production (2007–2011). The shift towards digitalization could be seen to have started in the mid-1990s, when the value added in the electronics and electrical products sector exceeded both the wood and paper and machinery and equipment sectors. In recent years, between 2015 and 2020, the GDP has steadily grown (Statistics Finland), and there is also evidence of manufacturing jobs being reshored to Finland lately (Kaivo-Oja *et al*. 2018).

3.2 DIGITALIZATION POLICY IN FINLAND

Digitalization and Industry 4.0 under the term "Industrial Internet" can be found in policy documents from the era of the Katainen and Stubb governments (2011–2015). In Finland, strategizing preset visions and plans for the Industry 4.0 transition was the first step on the roadmap of Industry 4.0. For example, the governmental program of 2011 proffered the introduction of intelligent solutions in all sectors of society and the creation of intelligent strategies for each of the ministries (Prime Minister's Office 2011). In the *Industrial Competitiveness Approach* (Känkänen *et al*. 2013), information and communications technology (ICT) is recognized as not only a support function but a "bloodline" for the manufacturing industry.

Further development by the Ministry of Employment and the Economy ([MEE] 2014) has involved creating the prerequisites and support for the Industrial Internet's implementation. The report presented actions for promoting digitalization as a value creator of industrial manufacturing for the MEE itself, for the Finnish Funding Agency for Technology and Innovation (Tekes – an activator and funder of business, higher education, and research institutions' R&D projects), for the Ministry of Transport and Communications and for the Ministry of Education. Following this trend, in 2014, the Prime Minister's Office commissioned an assessment on the challenges and opportunities of the "Finnish Industrial Internet" (Ailisto *et al*. 2015). The results were reported in 2015, and another set of recommendations were suggested.

The Sipilä government's (2015–2019) program (Prime Minister's Office 2015) presented a new strategy that focused on the digitalization of public services and the

creation of a growth environment. This led to the second phase on the Industry 4.0 roadmap, which emphasized the adoption of new technologies and solutions development by fostering a culture of experimentation. One action point of the program was to establish a governmental program for the Internet of Things. Later on, in 2017, AI was promoted to a strategic spearhead, and a roadmap for integrating AI into the Finnish society and businesses was created (MEE 2019). Ecosystem thinking also became visible in the national policy and was prominently featured in the governmental action plan for 2018–2019 (Finnish Government 2018). This can be viewed as the third step of Industry 4.0 implementation in Finland – ecosystemic collaboration and data-driven value creation.

The Rinne (2019) and the current Marin (2019–) governmental programs (Finnish Government 2019a, 2019b) advocated for a switch to sustainability, inclusiveness and carbon-neutrality. Ecosystemic thinking has also been strongly featured (e.g., “Ecosystems will be the engines of sustainable growth” [Finnish Government 2019a, 2019b]). The Research, Development, and Innovation Roadmap (Finnish Government 2020) lists three strategic development targets: competence, a new partnership model and an innovative public sector. A key figure in operationalizing the strategy is Business Finland (former Tekes), and their programs and terminology provide insight on how Industry 4.0 has been interpreted in Finland. Their policy is also transitioning towards sustainability through “Sustainable Manufacturing Finland” (Mattila 2020). This program shares the “twin transition” ideology of the EU’s Green Deal, and implies promoting digitalization – especially through a platform economy, artificial intelligence (AI), and data-driven business models – while simultaneously increasing the sustainability of the business in terms of a circular economy, lowered carbon emissions and inclusion. This fourth step of the progression can be called “Sustainable Industry 4.0 Ecosystems.”

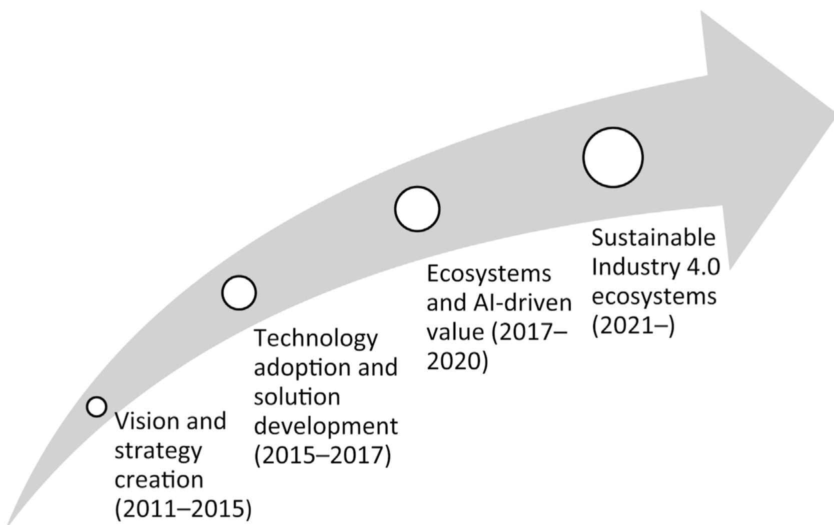

FIGURE 3.1 Evolution of the Industry 4.0 strategy in Finland.

It should be noted that despite Finland being on the forefront of digitalization, there has not been a national definition for Industry 4.0. "Industrial Internet" made a somewhat brief appearance in the mid-2010s, but it was soon superseded by digitalization and individual areas of Industry 4.0, such as the Internet of Things (IoT) and AI. Following, Kaivo-Oja *et al*. (2018) defined that Industry 4.0 "is marked by highly developed automation and digitization processes and by the use of electronics and information technologies (IT) in manufacturing and services." To summarize how this has taken place, Figure 3.1 illustrates key developments in the national Industry 4.0 strategy in Finland.

3.3 METHODOLOGY

To conduct more thorough investigations of drivers, barriers, and future opportunities for Finnish Industry 4.0 implementation, a framework of these three dimensions was first created based on a literature review of the subject. The most relevant literature sources identified include Türkes *et al*. (2019), Stentoft *et al*. (2019), Rajput and Singh (2019), Moeuf *et al*. (2020), Müller and Voigt (2018), Kamble *et al*. (2018), and Horváth and Szabó (2019). An initial search was constructed using the search strings "Industry 4.0 in Finland" and "Drivers, barriers and opportunities of Industry 4.0" in Google Scholar. After that, the best papers and reports specifically relevant to the Finnish context were included in the study. The contents of the papers and reports were carefully reviewed, and Industry 4.0-based barriers, drivers, and opportunities were handpicked using the identified documents.

Subsequently, each individual item's relevance to Finland was analyzed based on existing policies and research. This was complemented by the authors' expertise on the topic that was gained, for example, from conducting several research projects, such as Reboot IoT Factory (2018–2021). The project is one of the first pilot projects in the Finnish digitalization program Reboot IoT Finland, which aims to facilitate the digital transformation of Finnish manufacturing. Table 3.1 presents the drivers, barriers, and opportunities in order by their perceived relevance to the Finnish context, explained in the following sections.

TABLE 3.1
Drivers, Barriers, and Opportunities of Industry 4.0 in Finland

Drivers	Barriers	Opportunities
High market competition	Single source solutions for unique needs are difficult to find	Growing global markets
National infrastructure that supports Industry 4.0	SMEs lacking monetary and strategic support	Competitive advantage through smart and sustainable manufacturing
Culture of innovation and R&D	SMEs hesitance to digitalize their operations	Involving SMEs to create new innovations in business ecosystems
Highly skilled workforce	Aging population, less potential employees with new skills	Societies as innovation platforms

Drivers	Barriers	Opportunities
Culture of triple helix collaboration	Issues related to data security, ownership, and trust in digital ecosystems	Collaboration platforms for industrial symbiosis, value creation networks and business ecosystems
Business model innovation	Lack of methodological approaches, such as best-practice-examples, toolsets and distilled information	Sustainable business models, organizations, processes, and products

3.4 INDUSTRY 4.0 DRIVERS IN FINLAND

Changes in economic and social life conditions have led to reliance on modern digital technologies signifying high-tech strategies and innovations as the underlying factors of Industry 4.0 and its development (Türkes *et al*. 2019). The Finnish manufacturing industry has initiated digitalization processes to increase productivity, which is required for competency in the global market and retaining the industry in Finland. The industry has become a part of the "new globalization" trend the world has been facing since 1990 (Ali-Yrkkö *et al*. 2017).

Currently, Finnish factories are in very close competition with their global counterparts. High labor and logistics costs have resulted in decreased cost competitiveness. The total logistics costs of Finnish manufacturing firms are approximately 14 percent of the turnover, whereas in Swiss manufacturing firms, they are approximately 8 percent. The difference is partly attributable to the long transportation distance to export markets (Solakivi *et al*. 2018). To beat the global competition, the Finnish manufacturing industry relocated their activities and tasks to locations abroad to optimize their efficiency and the reconfiguration of their value-chains (Kaivo-Oja *et al*. 2018). Because the global markets are becoming more heterogenous over time, a growing number of competing companies opting for technological advancements have abruptly made it essential for Finnish companies to reduce their time-to-market rates, to be among the first movers and to gain a decisive advantage over their competitors by increasing their innovation capability, productivity, and efficiency.

Political support from different actors in Finland has played a vital role in shaping the Industry 4.0-based economic development in the information and telecommunications and healthcare and engineering sectors. With this support, Finland has been able to provide the necessary modern and robust infrastructure to support digitalization. Connectivity is targeted through immense 5G initiatives that aim to serve an extensive range of sectors, such as connected automobility, e-health and energy management. Furthermore, the infrastructure supports the use of advanced digital technologies, such as AI, the IoT, cyber-physical systems (CPS), and big data in general. More specifically, Finland has been marked as the most advanced country to uptake cloud services (European Commission 2020).

The general aim of Industry 4.0 is to eradicate the boundaries between the digital and the physical world, acquiring highly skilled Industry 4.0 human operators for the accurate exchange of information between intelligent support systems, supported by

their robust aids and capabilities (Schmidt *et al.* 2015). In Finland, such production systems support the digitization of production units by successful human-robot collaboration, thereby building smart and intelligent factories with multiplied efficiency levels in terms of monitoring and supervision support systems, digital computing systems, virtual trainings, and decision support systems. A highly educated workforce/human capital in terms of digitally skilled labor and ICT specialists has supported Finland in becoming a digitalization leader (European Commission 2020). This has been further reinforced by the Finnish national core curriculum for basic education (Finnish National Agency for Education 2020), which includes coding and programming from the very beginning of students' school education. For example, sixth-grade students studying handicrafts learn to embed automation as a part of their product, whereas students studying mathematics learn to solve problems in a graphical programming environment. Furthermore, in secondary school (grades 7–9), they learn how to use their skills to produce digital work individually and in a collaborative environment.

Finland has a tradition of research – business collaboration, and around 70 percent of large businesses collaborate on innovation with higher education or research institutions (OECD 2013, 2017). While the percentage of large businesses collaborating with research and higher education institutions is the highest in the world, the SME portion is only ranked fourth, after Great Britain, Belgium, and Austria. Collaboration between companies and research organizations produces new Industry 4.0-based innovations and operators in the 'factory of the future' (Isabel *et al.* 2019). Successful collaborations have presented key innovations together with smart technologies based on CPS, the IoT, cloud computing, big data, and 3D printing, leading to increased efficiency and competitiveness.

Industry 4.0 has established digitalization trends that vary from country to country. While the digitalization policies of Germany and Japan have focused primarily on product quality (Türkes *et al.* 2019), the US and China have emphasized efficient product delivery and cutting the costs, respectively (Urciuoli *et al.* 2013; Müller and Daeschle 2018; Zhu and Geng 2013). Large businesses in Finland have developed their business models based on new product and service offerings and the simplification of smart products based on quality. Finnish manufacturers distinguish themselves based on the reliability and flexibility they offer in the regional balancing of their value chains (Kaivo-Oja *et al.* 2018). This allows Finnish manufacturers to synchronize their operations with all the stakeholders in the value-chain and to precisely be more responsive to customer needs. Additionally, strong customer orientation, flexibility, and state-of-the-art technologies have resulted in the dynamic capabilities needed for Industry 4.0 development (Xu *et al.* 2018). In summary, the high process digitalization of the country is based on high-end governmental financial support, an educated workforce, technological innovation and close industry – research collaborations.

3.5 INDUSTRY 4.0 BARRIERS IN FINLAND

The Finnish industry is characterized more by customized offerings, which makes it hard to find off-the-shelf/single-source solutions. To find holistic solutions,

companies need the competence to define their own needs and collaborate with the SMEs to provide expanded solutions. Subsequently, without the large budget required for SMEs to match big corporations, it becomes a huge challenge for SMEs to achieve visibility, thereby making it difficult to be competitive and seen as valuable for strategic partnership.

Finland lacks the culture and resources for later-stage venture capital investments compared to many other countries (Saarikoski *et al.* 2014), which hinders its SMEs' growth in international markets. Furthermore, while the start-up culture itself is quite strong, there is a lack of start-ups oriented towards manufacturing industry innovation. In addition to venture capital, SMEs, particularly microenterprises, are underrepresented in government support for companies. For instance, micro and small enterprises only represent 6.2 percent and 22 percent, respectively, of subsidy receivers (Statistics Finland 2020). Additionally, regarding Industry 4.0, digitalization money might not be targeted towards manufacturing.

Digitalization requires investments in new technologies, such as artificial intelligence, digital twins, advanced robotics, and virtual reality. The field of new technologies is very wide and disperse, often without standards. However, even if the technology sounds lucrative, it is often hard to estimate the business benefits it can provide. Even large companies do not have enough resources to identify, evaluate, test, and pilot all digitalization solutions to gain their full benefits. Testing is required to achieve confidence in actual large-scale investments and deployment, and change management is required throughout the organization while processes become more autonomous. For SMEs and mid-cap size manufacturing, which comprise most Finnish exports, the challenge is even more severe. The profitable digitalization solutions identified by the forerunner companies would have to be scaled down to typically low-volume SME production. Additionally, the investment level needs to be lower for new technology in SMEs, as they may lack digital expertise.

Finland has experienced a natural decrease in population growth leading to a lack of young people for future the technological development (Santos *et al.* 2017), creating a gap between the skills of traditional factory workers and the new skills needed on the job. This is significant, as a Deloitte study has predicted that technology will likely create more jobs in the manufacturing industry (Wellener *et al.* 2020), posing a challenge for procuring skilled and motivated labor for the industry in Finland. Thus, as production costs are high in Finland and most likely will stay that way, the level of automation and optimization of production processes must be under constant development to keep the competitive edge.

Despite a well-established digital ecosystem, the country still needs substantial investment from companies in data security and protection standards. Further, the companies need to understand data security laws and standardization issues related to digital strategy and working with machines (Wang *et al.* 2015). These issues can be further tackled by offering new incentive initiatives and funding programs. Another shortcoming stems from the legal and contractual uncertainties in using certain technologies; however, these can be solved by developing and adopting legal frameworks about big data collection, data privacy and data security.

Finally, companies joining in implementing Industry 4.0 lack best-practice examples from successful organizations. Sharing methodological toolkits in the ecosystems will thereby create enormous opportunities for start-ups and SMEs in terms of providing a baseline for strategic and market orientations, exemplifying business operations (Sahi *et al.* 2020). Thus, while Finland is still striving to offer large-scale digitalization solutions in the manufacturing industry as a country with both strong ICT and manufacturing verticals, it could do much more.

3.6 INDUSTRY 4.0 OPPORTUNITIES IN FINLAND

Industry 4.0 linked with high-level digitalization has created the opportunity for Finnish companies to join global value chains and understand the diversity of different industrial branches, their economic geography and their supply chain implementation strategies (Ailisto *et al.* 2015). As a result, this kind of multidimensional global understanding will help Finnish companies to attract job markets and foreign direct investments. Finland's strengths as a pilot plant site due to its low collaboration barrier, the availability of technology and its highly skilled workforce should be further harnessed.

Industry 4.0 has and continues to transform the definition and skills required for workers. Analytical thinking and innovation, active learning, complex problem-solving, critical thinking and analysis, creativity, originality and initiative, leadership and social influence, technology uses monitoring and control, and technology designs are the top skills for 2025 according to the World Economic Forum (WEF 2020). The education curriculum and systems must evolve to support the lifelong learning of blue-collar workers and white-collar workers as well as to attract individuals to counter the labor shortage in the manufacturing industry. To ensure the rapid reskilling of society, agile education is required to ensure that companies can leverage novel solutions.

Previously, SMEs in Finland have lagged behind in adopting Industry 4.0 due to multiple factors, such as lack of resources compared to larger companies and a lower degree of initiative to apply the technologies within their business networks (Stentoft *et al.* 2019). However, SMEs and start-ups are now seen as tools for enhancing the strategic and operative performance of the traditional companies (Ailisto *et al.* 2015). Ecosystem collaboration projects and the growth of a start-up scene that fosters the creation of more Industry 4.0-oriented start-ups has resulted in companies such as Meluta (acoustic and vibroacoustic measurements) and Visual Components (3D manufacturing simulation). However, even though SMEs are involved in Industry 4.0 implementation as technology and solution providers, the level of SMEs' Industry 4.0 maturity in absorptive capacity and knowledge acquisitions (Müller *et al.* 2020) could be further improved.

The value created based on Industry 4.0 and digitalization in Finland has utilized smart components, sensors, data sharing standards, and interfaces building autonomous and integrative architectures. Currently, it is necessary to focus on the interconnected systems forming trusted and collaborative networks, thus creating a need for innovative societies. These platforms and ecosystems based on innovative societies are seizing new opportunities in building new strategic and operative business

capabilities to integrate processes, structures, visions, information systems, data and competencies through active experience sharing. In addition, cross-company collaborations for exchanging smart data, resources, products and materials form value-creating networks, offering new opportunities for industrial symbiosis and thus creating ways for closed-loop product lifecycles through efficient coordination (Schuh *et al.* 2014). In an attempt to capture further value, Finland is currently in the stage of moving past ecosystemic collaboration into collaboration between ecosystems.

Another major global disruptor of late has been platform economy, with giants such as Google or Amazon aggressively utilizing the "winner takes all" dynamic to capture the B2C market in digital services. To address these developments, the EU has devised the European Data Strategy, which established a regulatory framework for handling and utilizing data in business value creation. It specifically assesses value capturing in the emerging B2B platform economy based on data sharing between companies, organizations, and the public sector. Implementations of the data strategy include the International Data Spaces (IDS) and GAIA-X architectures, which aim for a federated architecture of services for B2B data sharing and value creation. At the close of 2020, GAIA-X was also emerging in Finland. The Finnish hub is forming, and the first GAIA-X members have included VTT, SITRA, CSC, and the Vastuu Group. The potential for cross-vertical data sharing in the Industry 4.0 verticals has been recognized. However, use cases are still few, and opportunities are more unclear in contrast to some of the other verticals moving forward in the EU, such as mobility-as-a-service and healthcare. Nevertheless, Finland has the prerequisites in place and has profiled itself along with the Netherlands as one of the frontrunners in charting opportunities arising from GAIA-X (Vahti 2020).

Moreover, the technological advancements and inclinations based on Industry 4.0 require companies to transform from a linear to a circular economy and forge a path towards sustainability (Rajput and Singh 2019). Manufacturing companies in Finland are also striving to attain sustainable operations and achieve circular economy principles. Exploring the opportunities created by the technological revolution, companies are transforming their supply chains by generating a vast amount of data concerning raw materials, waste monitoring, energy consumption, closed loop supply chains, and assessments of real-time information (Geissdoerfer *et al.* 2017). In a nutshell, if companies rightfully use the opportunities provided by Industry 4.0, they can successfully develop sustainability-based business models, thereby maintaining a balance between economic, environmental, and social aspects (Rajput and Singh 2019).

3.7 DISCUSSION AND CONCLUSION

Throughout the 2010s, digitalization was recognized as a key factor of Finland's global competitiveness, and the elements of Industry 4.0 have been quite successfully implemented through consistent national policy. This has been supported by a high level of education and the development of a supporting national infrastructure (OECD 2017). The traditions of a collaborative and trust-based business environment, triple helix collaboration, and a strong culture of experimentation, rapid testing, and

innovation have advanced Industry 4.0 implementation (Ailisto *et al.* 2015; Schuh *et al.* 2014). Moreover, high levels of R&D investments and a transition to innovation ecosystem-based thinking for value creation (Finnish Government 2018) helped Finland to reach its position as one of the global front-runners of Industry 4.0 maturity in 2019 (Atik and Ünlü 2019; Castelo-Branco *et al.* 2019).

However, areas of improvement and barriers to implementation have been recognized. Finland's population is one of the oldest in Europe and is rapidly aging (Finnish Institute for Health and Welfare 2020), causing serious concerns for recruiting a workforce with an up-to-date set of skills. While major companies are advancing in digitalization, the knowledge is not always disseminated throughout their supply networks. In the manufacturing sector and within SMEs, there is still room for the implementation of Industry 4.0 tools, particularly related to analytics, as noted by Mittal *et al.* (2020). Improving digital skills in SMEs is also a key objective in the national AI 4.0 program launched in late 2020 (MEE 2020).

The focus on high-value-adding niche markets indicates that implementing off-the-shelf solutions is often impossible, resulting in higher costs and lead times in the implementation of digital solutions. This contributes to another barrier of Industry 4.0 implementation, as costs are often assessed as high compared to the benefits. This holds particularly true for SMEs, and the barriers of lack of expertise as well as unwillingness to commit to a long-term Industry 4.0 strategy or to invest in technology that could soon be obsolete (Moeuf *et al.* 2020) can be recognized in Finnish SMEs as well.

Many future opportunities can be recognized regarding the current twin transition towards digitalization and sustainability. With the ecosystem thinking that has already been established, a current initiative to harness the knowledge and innovation created across vertical clusters aims to establish a national "supercluster" or an "ecosystem of ecosystems" to nationally coordinate these activities. This Sustainable Industry X (SIX) initiative (Figure 3.2) aims to integrate existing clusters and ecosystems, the best practices, national and EU policies, industry and stakeholder needs, and triple helix collaboration. It is currently in an early start-up phase, but if successful, it could boost national competitiveness and support the goals of sustainable manufacturing in the near future.

Other future opportunities can be found within the current ecosystem collaboration models. Many of these initiatives are project-based, and they operate based on public funding. The challenge of sustaining them after the funding period has passed has not been fully solved. Furthermore, finding more explicit value propositions from research to industry and vice versa could support the creation of partnerships spanning beyond public funding of ecosystem collaboration projects. Moreover, active information sharing and working together could establish a basis of trust and more sustainable collaboration. The research community is also responsible for finding these new management qualities and practices (Horváth and Szabó 2019).

This leads to another future challenge for increasing SME participation in these innovation ecosystems, both as solution providers and solution utilizers. Due to their limited resources and ability to take risks, SMEs need implementation support to exploit and to explore Industry 4.0 opportunities, as observed by Müller *et al.* (2020). Future opportunities also exist within the platform and data economies. Last, to

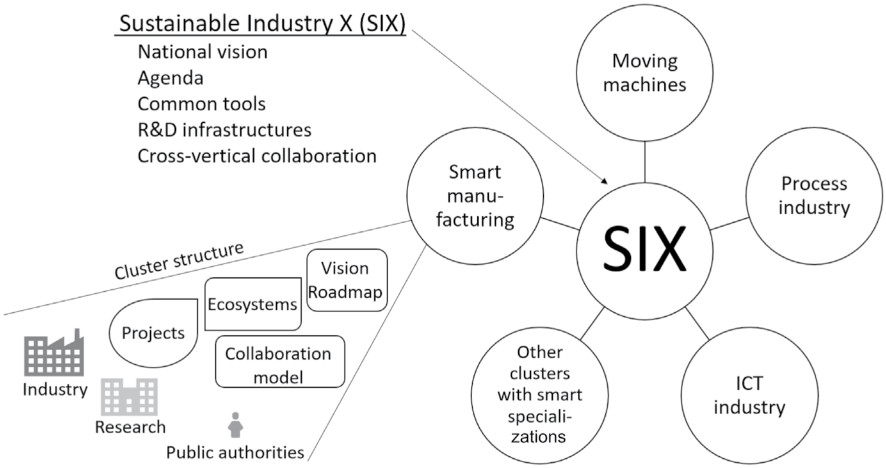

FIGURE 3.2 Initiative for establishing a national industry program SIX

counter the issues stemming from the aging population and the shifting required skillset, all parties of the triple helix have to find ways to further promote lifelong learning and to quickly adapt to the changing requirements of workforce competences (Isabel *et al*. 2019).

Overall, as a society, Finland has remained at the forefront of digitalization for some time now, which has also enabled Finnish industries to successfully adopt and develop Industry 4.0 solutions and new operating models. However, structural characteristics of the society, such as the aging population and high labor cost, indicate that keeping on top of global trends and technological change remains necessary for Finland to remain globally competitive. How to adapt and stay on the forefront of innovation remains a primary concern, as sustainability and circular-economy-based operating models are becoming a new standard in global business.

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